Future climate change is likely to continue to adversely affect human health in Asia (high confidence).
Increases in endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected in East, South and South-East Asia, due to projected changes in the hydrological cycle associated with global warming [10.4.5]. Increases in coastal water temperature would exacerbate the abundance and/or toxicity of cholera in South Asia [10.4.5]. Natural habitats of vector-borne and water-borne diseases are reported to be expanding [10.4.5].

Multiple stresses in Asia will be further compounded in the future due to climate change (high confidence).
Exploitation of natural resources associated with rapid urbanisation, industrialisation and economic development in most developing countries of Asia has led to increasing air and water pollution, land degradation, and other environmental problems that have placed enormous pressure on urban infrastructure, human well-being, cultural integrity, and socio-economic settings. It is likely that climate change will intensify these environmental pressures and impinge on sustainable development in many developing countries of Asia, particularly in the South and East [10.5.6].

Australia and New Zealand

The region is already experiencing impacts from recent climate change, and adaptation has started in some sectors and regions (high confidence).
Since 1950 there has been a 0.3 to 0.7°C warming in the region, with more heatwaves, fewer frosts, more rain in north-western Australia and south-western New Zealand, less rain in southern and eastern Australia and north-eastern New Zealand, an increase in the intensity of Australian droughts, and a rise in sea level of 70 mm [11.2.1]. Impacts are now evident in water supply and agriculture, changed natural ecosystems, reduced seasonal snow cover and glacier shrinkage [11.2.2, 11.2.3]. Some adaptation has occurred in sectors such as water, agriculture, horticulture and coasts [11.2.5].

The climate of the 21st century is virtually certain to be warmer, with changes in extreme events (medium to high confidence).
Heatwaves and fires are virtually certain to increase in intensity and frequency (high confidence) [11.3]. Floods, landslides, droughts and storm surges are very likely to become more frequent and intense, and snow and frost are likely to become less frequent (high confidence) [11.3.1]. Large areas of mainland Australia and eastern New Zealand are likely to have less soil moisture, although western New Zealand is likely to receive more rain (medium confidence) [11.3].

Without further adaptation, potential impacts of climate change are likely to be substantial (high confidence).

- As a result of reduced precipitation and increased evaporation, water security problems are very likely to intensify by 2030 in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions [11.4.1].
- Significant loss of biodiversity is projected to occur by 2020 in some ecologically rich sites including the Great Barrier Reef and Queensland Wet Tropics. Other sites at risk include Kakadu Wetlands, south-west Australia, sub-Antarctic islands and the alpine areas of both countries [11.4.2].
- Ongoing coastal development and population growth in areas such as Cairns and south-east Queensland (Australia) and Northland to Bay of Plenty (New Zealand) are projected to exacerbate risks from sea-level rise and increases in the severity and frequency of storms and coastal flooding by 2050 [11.4.5, 11.4.7].
- Risks to major infrastructure are likely to markedly increase. By 2030, design criteria for extreme events are very likely to be exceeded more frequently. These risks include the failure of flood protection and urban drainage/sewerage, increased storm and fire damage, and more heatwaves causing more deaths and more black-outs [11.4.1, 11.4.5, 11.4.7, 11.4.10, 11.4.11].
- Production from agriculture and forestry is projected to decline by 2030 over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits to agriculture and forestry are projected in western and southern areas and close to major rivers due to a longer growing season, less frost and increased rainfall [11.4.3, 11.4.4].

Vulnerability is likely to increase in many sectors, but this depends on adaptive capacity.

- Most human systems have considerable adaptive capacity. The region has well-developed economies, extensive scientific and technical capabilities, disaster-mitigation strategies, and biosecurity measures. However, there are likely to be considerable cost and institutional constraints to the implementation of adaptation options (high confidence) [11.5]. Some Indigenous communities have low adaptive capacity (medium confidence) [11.4.8]. Water security and coastal communities are most vulnerable (high confidence) [11.7].
- Natural systems have limited adaptive capacity. Projected rates of climate change are very likely to exceed rates of evolutionary adaptation in many species (high confidence) [11.5]. Habitat loss and fragmentation are very likely to limit species migration in response to shifting climatic zones (high confidence) [11.2.5, 11.5].
- Vulnerability is likely to rise as a consequence of an increase in extreme events. Economic damage from extreme weather is very likely to increase and provide major challenges for adaptation (high confidence) [11.5].
- Vulnerability is likely to be high by 2050 in a few identified hotspots (see Figure TS.12). In Australia, these include the Great Barrier Reef, eastern Queensland, the south-west, Murray-Darling Basin, the Alps and Kakadu; in New Zealand, these include the Bay of Plenty, Northland, eastern regions and the Southern Alps (medium confidence) [11.7].

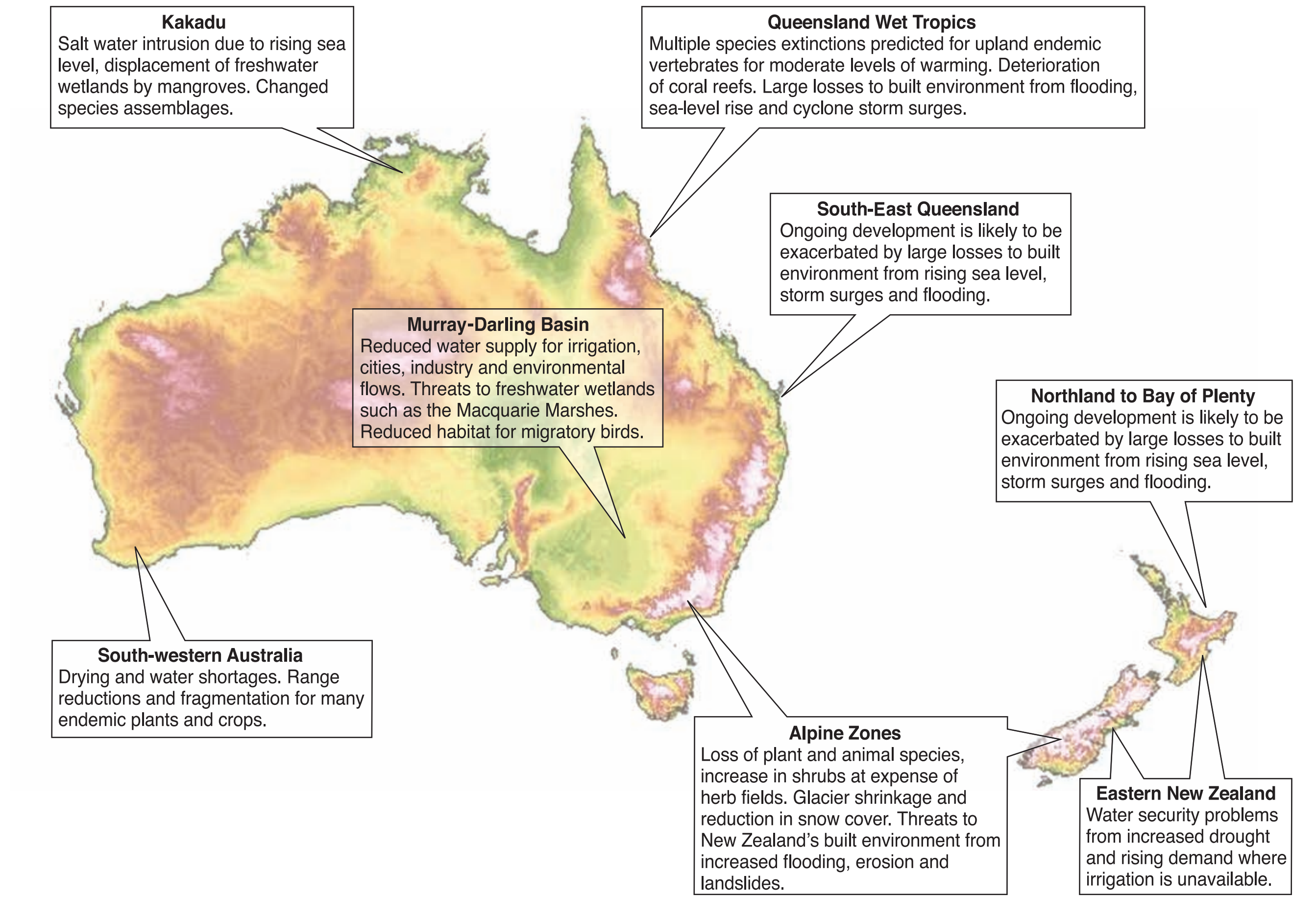


Figure TS.12. *Key hotspots in Australia and New Zealand, based on the following criteria: large impacts, low adaptive capacity, substantial population, economically important, substantial exposed infrastructure, and subject to other major stresses (e.g., continued rapid population growth, ongoing development, ongoing land degradation, ongoing habitat loss and threats from rising sea level). [11.7]*

Europe

For the first time, wide-ranging impacts of changes in current climate have been documented in Europe (very high confidence).

The warming trend and spatially variable changes in rainfall have affected composition and functioning of the cryosphere (retreat of glaciers and extent of permafrost) as well as natural and managed ecosystems (lengthening of growing season, shift of species and human health due to a heatwave of unprecedented magnitude) [12.2.1]. The European heatwave in 2003 (see Figure TS.13) had major impacts on biophysical systems and society (around 35,000 excess deaths were recorded) [12.6.1]. The observed changes are consistent with projections of impacts due to future climate change [12.4].

Climate-related hazards will mostly increase, although changes will vary geographically (very high confidence).

By the 2020s, increases are likely in winter floods in maritime regions and flash floods throughout Europe [12.4.1]. Coastal flooding related to increasing storminess (particularly in the north-east Atlantic) and sea-level rise are likely to threaten an additional 1.5 million people annually by the 2080s; coastal erosion is projected to increase [12.4.2]. Warmer, drier conditions will lead to more frequent and prolonged droughts (by the 2070s, today's 100-year droughts will return every 50 years or less in southern and south-eastern Europe), as well as a longer fire-season and increased fire risk, particularly in the Mediterranean region [12.3.1, 12.4.4]. A higher frequency of catastrophic fires is also expected on drained peatlands in central and eastern Europe [12.4.5]. The frequency of rockfalls will increase due to destabilization of mountain walls by rising temperatures and melting of permafrost [12.4.3].

Some impacts may be positive, such as reduced cold-related mortality because of increasing winter temperatures. However, on balance, without adaptive measures, health risks due to more frequent heatwaves, especially in southern, central and eastern Europe, flooding and greater exposure to vector- and food-borne diseases are anticipated to increase [12.4.11].

Climate change is likely to magnify regional differences in Europe's natural resources and assets (very high confidence).

Climate-change scenarios indicate significant warming (A2: 2.5 to 5.5°C; B2: 1 to 4°C), greater in winter in the north and in summer in south and central Europe [12.3.1]. Mean annual precipitation is projected to increase in the north and decrease in the south. Seasonal changes, however, will be more pronounced: summer precipitation is projected to decrease by up to 30 to 45%

over the Mediterranean Basin, and also over eastern and central Europe and, to a lesser degree, over northern Europe even as far north as central Scandinavia [12.3.1]. Recruitment and production of marine fisheries in the North Atlantic are likely to increase [12.4.7]. Crop suitability is likely to change throughout Europe, and crop productivity (all other factors remaining unchanged) is likely to increase in northern Europe, and decrease along the Mediterranean and in south-east Europe [12.4.7]. Forests are projected to expand in the north and retreat in the south [12.4.4]. Forest productivity and total biomass are likely to increase in the north and decrease in central and eastern Europe, while tree mortality is likely to accelerate in the south [12.4.4]. Differences in water availability between regions are anticipated to become more pronounced: annual average runoff increasing in north/north-west, and decreasing in south/south-east Europe (summer low flow is projected to decrease by up to 50% in central Europe and by up to 80% in some rivers in southern Europe) [12.4.1, 12.4.5].

Water stress is likely to increase, as well as the number of people living in river basins under high water stress (high confidence).

Water stress is likely to increase over central and southern Europe. The percentage of area under high water stress is likely to increase from 19% to 35% by the 2070s, and the number of people at risk from 16 to 44 million [12.4.1]. The regions most at risk are southern Europe and some parts of central and eastern Europe [12.4.1]. The hydropower potential of Europe is expected to decline on average by 6%, and by 20 to 50% around the Mediterranean by the 2070s [12.4.8.1].

It is anticipated that Europe's natural systems and biodiversity will be substantially affected by climate change (very high confidence). The great majority of organisms and ecosystems are likely to have difficulty in adapting to climate change (high confidence).

Sea-level rise is likely to cause an inland migration of beaches and loss of up to 20% of coastal wetlands [12.4.2.], reducing the habitat availability for several species that breed or forage in low-lying coastal areas [12.4.6]. Small glaciers will disappear and larger glaciers substantially shrink (projected volume reductions of between 30% and 70% by 2050) during the 21st century [12.4.3]. Many permafrost areas in the Arctic are projected to disappear [12.4.5.]. In the Mediterranean, many ephemeral aquatic ecosystems are projected to disappear, and permanent ones shrink and become ephemeral [12.4.5]. The northward expansion of forests is projected to reduce current tundra areas under some scenarios [12.4.4]. Mountain communities face up to a 60% loss of species under high-emissions scenarios by 2080 [12.4.3]. A large percentage of the European flora (one study found up to 50%) is likely to become vulnerable, endangered or committed to extinction by the end of this century [12.4.6]. Options for adaptation are likely to be limited for many organisms and ecosystems. For example, limited dispersal is very likely to reduce the range of most reptiles and amphibians [12.4.6]. Low-lying, geologically subsiding coasts are likely to be unable to adapt to sea-level rise [12.5.2]. There are no obvious climate adaptation options for either tundra or alpine vegetation [12.5.3]. The adaptive capacity of ecosystems can be enhanced by reducing human stresses [12.5.3, 12.5.5]. New sites for conservation may be needed because climate change is very likely to alter conditions of suitability for many species in current sites (with climate change, to meet conservation goals, the current reserve area in the EU would have to be increased by 41%) [12.5.6].

Nearly all European regions are anticipated to be negatively affected by some future impacts of climate change and these will pose challenges to many economic sectors (very high confidence).

In southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability. In northern Europe, climate change is initially projected to bring mixed effects, including some benefits, but as climate change continues, its negative effects are likely to outweigh its benefits [12.4].

Agriculture will have to cope with increasing water demand for irrigation in southern Europe due to climate change (e.g., increased water demand of 2 to 4% for maize cultivation and 6 to 10% for potatoes by 2050), and additional restrictions due to increases in crop-related nitrate leaching [12.5.7]. Winter heating demands are expected to decrease and summer cooling demands

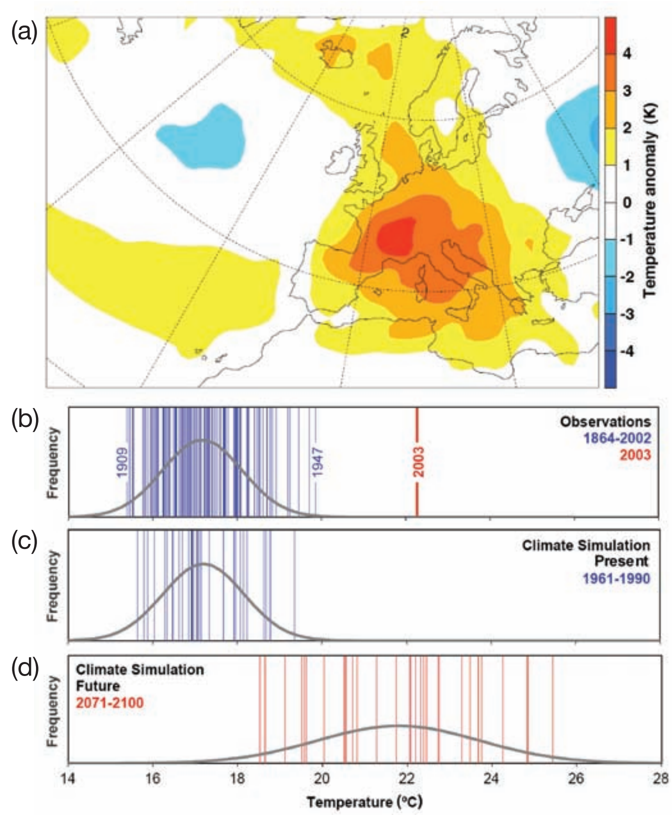


Figure TS-13. *Characteristics of the summer 2003 heatwave: (a) JJA temperature anomaly with respect to 1961-1990; (b-d) June, July, August temperatures for Switzerland; (b) observed during 1864-2003; (c) simulated using a regional climate model for the period 1961-1990; (d) simulated for 2071-2100 under the SRES A2 scenario. The vertical bars in panels (b-d) represent mean summer surface temperature for each year of the time period considered; the fitted Gaussian distribution is indicated in black. [F12.4]* to increase due to climate change: around the Mediterranean, 2 to 3 fewer weeks in a year will require heating but an additional 2 to 5 weeks will need cooling by 2050 [12.4.8]. Peak electricity demand is likely to shift in some locations from winter to summer [12.4.8]. Tourism along the Mediterranean is likely to decrease in summer and increase in spring and autumn. Winter tourism in mountain regions is anticipated to face reduced snow cover (the duration of snow cover is expected to decrease by several weeks for each °C of temperature increase in the Alps region) [12.4.9, 12.4.11].

Adaptation to climate change is likely to benefit from experiences gained in reactions to extreme climate events, by specifically implementing proactive climate-change risk management adaptation plans (very high confidence).
Since the TAR, governments have greatly increased the number of actions for coping with extreme climate events. Current thinking about adaptation to extreme climate events has moved away from reactive disaster relief and towards more proactive risk management. A prominent example is the implementation in several countries of early-warning systems for heatwaves (Portugal, Spain, France, UK, Italy, Hungary) [12.6.1]. Other actions have addressed long-term climate change. For example, national action plans have been developed for adapting to climate change [12.5] and more specific plans have been incorporated into European and national policies for agriculture, energy, forestry, transport and other sectors [12.2.3,12.5.2]. Research has also provided new insights into adaptation policies (e.g., studies have shown that crops that become less economically viable under climate change can be profitably replaced by bioenergy crops) [12.5.7].

Although the effectiveness and feasibility of adaptation measures are expected to vary greatly, only a few governments and institutions have systematically and critically examined a portfolio of measures. As an example, some reservoirs used now as a measure for adapting to precipitation fluctuations may become unreliable in regions where long-term precipitation is projected to decrease [12.4.1]. The range of management options to cope with climate change varies largely among forest types, with some types having many more options than others [12.5.5].

Latin America

Climatic variability and extreme events have been severely affecting the Latin America region over recent years (high confidence).
Highly unusual extreme weather events have recently occurred, such as Venezuelan intense rainfall (1999, 2005), flooding in the Argentine Pampas (2000-2002), Amazon drought (2005), hail storms in Bolivia (2002) and the Greater Buenos Aires area (2006), the unprecedented Hurricane Catarina in the South Atlantic (2004), and the record hurricane season of 2005 in the Caribbean Basin [13.2.2]. Historically, climate variability and extremes have had negative impacts on population, increasing mortality and morbidity in affected areas. Recent developments in meteorological forecasting techniques could improve the necessary information for human welfare and security. However, the lack of modern observation equipment and badly-needed upper-air information, the low density of weather stations, the unreliability of their reports, and the lack of monitoring of climate variables hinder the quality of forecasts, with adverse effects on the public, lowering their appreciation of applied meteorological services, as well as their trust in climate records. These shortcomings also affect hydrometeological observing services, with a negative impact on the quality of early warnings and alert advisories (medium confidence) [13.2.5].

During the last few decades, important changes in precipitation and increases in temperature have been observed (high confidence).
Increases in rainfall in south-east Brazil, Paraguay, Uruguay, the Argentine Pampas, and some parts of Bolivia have had impacts on land use and crop yields and have increased flood frequency and intensity. On the other hand, a declining trend in precipitation has been observed in southern Chile, south-west Argentina, southern Peru, and western Central America. Increases in temperature of approximately 1°C in Mesoamerica and South America and of 0.5°C in Brazil have been observed. As a consequence of temperature increases, the trend in glacier retreat reported in the TAR is accelerating (very high confidence). This issue is critical in Bolivia, Peru, Colombia and Ecuador, where water availability has already been compromised either for consumption or hydropower generation [13.2.4]. These problems with supply are expected to increase in the future, becoming chronic if no appropriate adaptation measures are planned and implemented. Over the next decades Andean inter-tropical glaciers are very likely to disappear, affecting water availability and hydropower generation (high confidence) [13.2.4].

Land-use changes have intensified the use of natural resources and exacerbated many of the processes of land degradation (high confidence).
Almost three-quarters of the dryland surface is moderately or severely affected by degradation processes. The combined effects of human action and climate change have brought a decline in natural land cover, which continues to decline at very high rates (high confidence). In particular, rates of deforestation of tropical forests have increased during the last 5 years. There is evidence that biomass-burning aerosols may change regional temperature and precipitation in the southern part of Amazonia (medium confidence). Biomass burning also affects regional air quality, with implications for human health. Land-use and climate changes acting synergistically will increase vegetation fire risk substantially (high confidence) [13.2.3, 13.2.4].

The projected mean warming for Latin America to the end of the 21st century, according to different climate models, ranges from 1 to 4°C for SRES emissions scenario B2 and from 2 to 6°C for scenario A2 (medium confidence).
Most GCM projections indicate rather larger than present (positive and negative) rainfall anomalies for the tropical portions of Latin America and smaller ones for extra-tropical South America. Changes in temperature and precipitation will have especially severe impacts on already vulnerable hotspots,

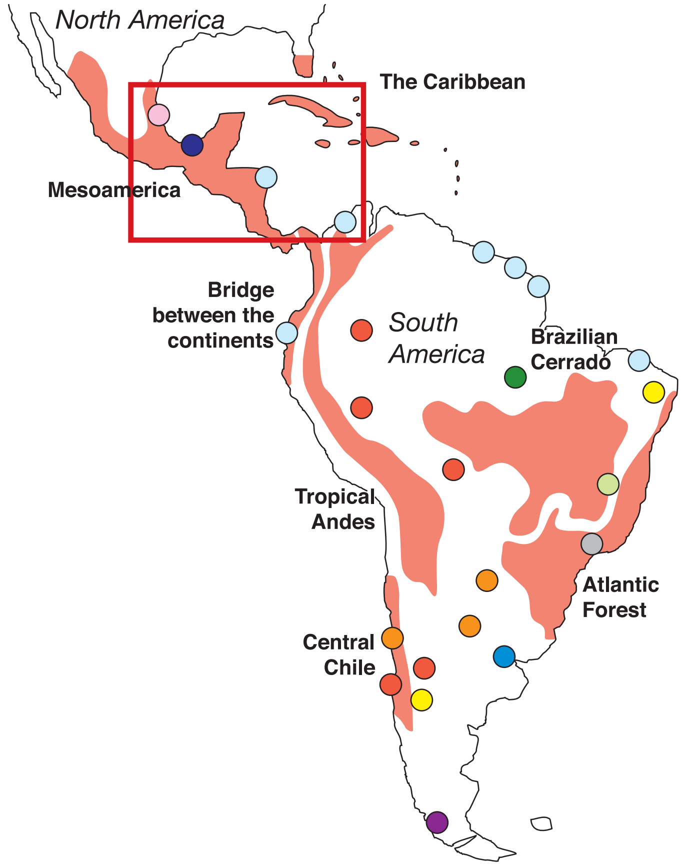
identified in Figure TS.14. In addition, the frequency of occurrence of weather and climate extremes is likely to increase in the future; as is the frequency and intensity of hurricanes in the Caribbean Basin [13.3.1, 13.3.1].

Under future climate change, there is a risk of significant species extinctions in many areas of tropical Latin America (high confidence).
Gradual replacement of tropical forest by savannas is expected by mid-century in eastern Amazonia and the tropical forests of central and southern Mexico, along with replacement of semi-arid by arid vegetation in parts of north-east Brazil and most of central and northern Mexico, due to increases in temperature and associated decreases in soil water (high confidence) [13.4.1]. By the 2050s, 50% of agricultural lands are very likely to be subjected to desertification and salinisation in some areas (high confidence) [13.4.2]. There is a risk of significant biodiversity loss through species extinction in many areas of tropical Latin America. Seven out of the world's twenty-five most critical places with high endemic species concentrations are in Latin America, and these areas are undergoing habitat loss. Biological reserves and ecological corridors have been either implemented or planned for the maintenance of biodiversity in natural ecosystems, and these can serve as adaptation measures to help protect ecosystems in the face of climate change [13.2.5].

By the 2020s, the net increase in the number of people experiencing water stress due to climate change is likely to be between 7 and 77 million (medium confidence).
For the second half of the 21st century, the potential water availability reduction and the increasing demand from an increasing regional population would increase these figures to between 60 and 150 million [13.4.3].

Generalised reductions in rice yields by the 2020s, as well as increases in soybean yields in temperate zones, are likely when CO_2 effects are considered (medium confidence).
For other crops (wheat, maize), the projected response to climate change is more erratic, depending on the chosen scenario. Assuming low CO_2 fertilisation effects, the number of additional people at risk of hunger under the A2 scenario is likely to reach 5, 26 and 85 million in 2020, 2050 and 2080, respectively (medium confidence). Livestock and dairy productivity is likely to decline in response to increasing temperatures [13.4.2].

The expected increases in sea-level rise, weather and climatic variability and extremes are very likely to affect coastal areas (high confidence).
During the last 10 to 20 years, the rate of sea-level rise increased from 1 to 2-3 mm/year in south-eastern South America [13.2.4]. In the future, sea-level rise is projected to cause an increased risk of flooding in low-lying areas. Adverse impacts would be observed on (i) low-lying areas (e.g., in El Salvador, Guyana, the coast of the province of Buenos Aires), (ii) buildings and tourism (e.g., in Mexico, Uruguay), (iii) coastal morphology (e.g., in Peru), (iv) mangroves (e.g., in Brazil, Ecuador, Colombia, Venezuela), (v) availability of drinking water on the Pacific coast of Costa Rica, Ecuador and the Rio de la Plata estuary [13.4.4].



- Coral reefs and mangroves seriously threatened with warmer SST
- Under the worst sea-level rise scenario, mangroves are very likely to disappear from low-lying coastlines
- Amazonia: loss of 43% of 69 tree species by the end of 21st century; savannisation of the eastern part
- Cerrados: Losses of 24% of 138 tree species for a temperature increase of 2°C
- Reduction of suitable lands for coffee
- Increases in aridity and scarcity of water resources
- Sharp increase in extinction of: mammals, birds, butterflies, frogs and reptiles by 2050
- Water availability and hydro-electric generation seriously reduced due to reduction in glaciers
- Ozone depletion and skin cancer
- Severe land degradation and desertification
- Rio de la Plata coasts threatened by increasing storm surges and sea-level rise
- Increased vulnerability to extreme events

Areas in red correspond to sites where biodiversity is currently severely threatened and this trend is very likely to continue in the future

Figure TS.14. *Key hotspots for Latin America, where climate change impacts are expected to be particularly severe. [13.4]*

Future sustainable development plans should include adaptation strategies to enhance the integration of climate change into development policies (high confidence).
Several adaptation measures have been proposed for coastal, agricultural, water and health sectors. However, the effectiveness of these efforts is outweighed by a lack of capacity-building and appropriate political, institutional and technological frameworks, low income, and settlements in vulnerable areas, among others. The present degree of development of observation and monitoring networks necessarily requires improvement, capacity-building, and the strengthening of communication in order to permit the effective operation of environmental observing systems and the reliable dissemination of early warnings. Otherwise, the Latin American countries' sustainable development goals are likely to be seriously compromised, adversely affecting, among other things, their capability to reach the Millennium Development Goals [13.5].

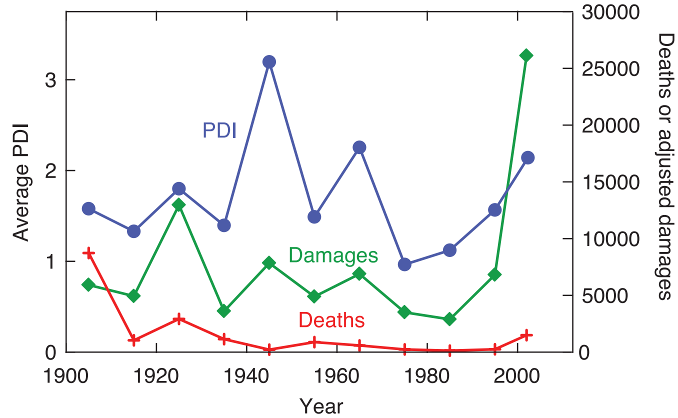


Figure TS.15. *Decadal average (6-year average for 2000-2005) hurricane total dissipated energy (PDI), loss of life, and inflation-adjusted economic damages (in thousands of US$) from hurricanes making landfall in the continental USA since 1900. [F14.1]*

North America

North America has considerable adaptive capacity, which has been deployed effectively at times, but this capacity has not always protected its population from adverse impacts of climate variability and extreme weather events (very high confidence).
Damage and loss of life from Hurricane Katrina in August 2005 illustrate the limitations of existing adaptive capacity to extreme events. Traditions and institutions in North America have encouraged a decentralised response framework where adaptation tends to be reactive, unevenly distributed, and focused on coping with rather than preventing problems. "Mainstreaming" climate change issues into decision making is a key prerequisite for sustainability [14.2.3, 14.2.6, 14.4, 14.5, 14.7].

Emphasis on effective adaptation is critical, because economic damage from extreme weather is likely to continue increasing, with direct and indirect consequences of climate change playing a growing role (very high confidence).
Over the past several decades, economic damage from hurricanes in North America has increased over fourfold (Figure TS.15), due largely to an increase in the value of infrastructure at risk [14.2.6]. Costs to North America include billions of dollars in damaged property and diminished economic productivity, as well as lives disrupted and lost [14.2.6, 14.2.7, 14.2.8]. Hardships from extreme events disproportionately affect those who are socially and economically disadvantaged, especially the poor and indigenous peoples of North America [14.2.6].

Climate change is likely to exacerbate other stresses on infrastructure, and human health and safety in urban centres (very high confidence).
Climate change impacts in urban centres are very likely to be compounded by urban heat islands, air and water pollution, ageing infrastructure, maladapted urban form and building stock, water quality and supply challenges, immigration and population growth, and an ageing population [14.3.2, 14.4.1, 14.4.6].

Coastal communities and habitats are very likely to be increasingly stressed by climate change impacts interacting with development and pollution (very high confidence).
Sea level is rising along much of the coast, and the rate of change is likely to increase in the future, exacerbating the impacts of progressive inundation, storm surge flooding, and shoreline erosion [14.2.3, 14.4.3]. Storm impacts are likely to be more severe, especially along the Gulf and Atlantic coasts [14.4.3]. Salt marshes, other coastal habitats and dependent species are threatened now and increasingly in future decades by sea-level rise, fixed structures blocking landward migration, and changes in vegetation [14.2]. Population growth and rising value of infrastructure in coastal areas increases vulnerability to climate variability and future climate change, with losses projected to increase if the intensity of tropical storms increases. Current adaptation to coastal hazards is uneven and readiness for increased exposure is low [14.2.3, 14.4.3, 14.5].

Warm temperatures and extreme weather already cause adverse human health effects through heat-related mortality, pollution, storm-related fatalities and injuries, and infectious diseases, and are likely, in the absence of effective countermeasures, to increase with climate change (very high confidence).
Depending on progress in health care, infrastructure, technology and access, climate change could increase the risk of heatwave deaths, water-borne diseases and degraded water quality [14.4.1], respiratory illness through exposure to pollen and ozone, and vector-borne infectious diseases (low confidence) [14.2.5, 14.4.5].

Climate change is very likely to constrain North America's already intensively utilised water resources, interacting with other stresses (high confidence).
Diminishing snowpack and increasing evaporation due to rising temperatures are very likely to affect timing and availability of water and intensify competition among uses [B14.2, 14.4.1]. Warming is very likely to place additional stress on groundwater availability, compounding the effects of higher demand from

economic development and population growth (medium confidence) [14.4.1]. In the Great Lakes and some major river systems, lower water levels are likely to exacerbate issues of water quality, navigation, hydropower generation, water diversions, and bi-national co-operation [14.4.1, B14.2].

Disturbances such as wildfire and insect outbreaks are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons, and to interact with changing land use and development affecting the future of wildland ecosystems (high confidence).
Recent climate trends have increased ecosystem net primary production, and this trend is likely to continue for the next few decades [14.2.2]. However, wildfire and insect outbreaks are increasing, a trend that is likely to intensify in a warmer future [14.4.2, B14.1]. Over the course of the 21st century, the tendency for species and ecosystems to shift northward and to higher elevations is likely to rearrange the map of North American ecosystems. Continuing increases in disturbances are likely to limit carbon storage, facilitate invasives, and amplify the potential for changes in ecosystem services [14.4.2, 14.4.4].

Polar Regions

The environmental impacts of climate change show profound regional differences both within and between the polar regions (very high confidence).
The impacts of climate change in the Arctic over the next hundred years are likely to exceed the changes forecast for many other regions. However, the complexity of responses in biological and human systems, and the fact that they are subject to additive multiple stresses, means that the impacts of climate change on these systems remain difficult to predict. Changes on the Antarctic Peninsula, sub-Antarctic islands and Southern Ocean have also been rapid, and in future dramatic impacts are expected. Evidence of ongoing change over the rest of the Antarctic continent is less conclusive and prediction of the likely impacts is thus difficult. For both polar regions, economic impacts are especially difficult to address due to the lack of available information [15.2.1, 15.3.2, 15.3.3].

There is a growing evidence of the impacts of climate change on ecosystems in both polar regions (high confidence).
There has been a measured change in composition and range of plants and animals on the Antarctic Peninsula and on the sub-Antarctic islands. There is a documented increase in the overall greenness of parts of the Arctic, an increase in biological productivity, a change in species ranges (e.g., shifts from tundra to shrublands), some changes in position of the northern limit of trees, and changes in the range and abundance of some animal species. In both the Arctic and Antarctic, research indicates that such changes in biodiversity and vegetation zone relocation will continue. The poleward migration of existing species and competition from invading species is already occurring, and will continue to alter species composition and abundance in terrestrial and aquatic systems. Associated vulnerabilities are related to loss of biodiversity and the spread of animal-transmitted diseases [15.2.2, 15.4.2].

The continuation of hydrological and cryospheric changes will have significant regional impacts on Arctic freshwater, riparian and near-shore marine systems (high confidence).
The combined discharge of Eurasian rivers draining into the Arctic Ocean shows an increase since the 1930s, largely consistent with increased precipitation, although changes to cryospheric processes (snowmelt and permafrost thaw) are also modifying routing and seasonality of flow [15.3.1, 15.4.1].

The retreat of Arctic sea ice over recent decades has led to improved marine access, changes in coastal ecology/biological production, adverse effects on many ice-dependent marine mammals, and increased coastal wave action (high confidence).
Continued loss of sea ice will produce regional opportunities and problems; reductions in freshwater ice will affect lake and river ecology and biological production, and will require changes in water-based transportation. For many stakeholders, economic benefits may accrue, but some activities and livelihoods may be adversely affected [15.ES, 15.4.7, 15.4.3, 15.4.1, 15.4.1].

Around the Antarctic Peninsula, a newly documented decline in krill abundance, together with an increase in salp abundance, has been attributed to a regional reduction in the extent and duration of sea ice (medium confidence).
If there is a further decline in sea ice, a further decline in krill is likely, impacting predators higher up the food chain [15.2.2, 15.6.3].

Warming of areas of the northern polar oceans has had a negative impact on community composition, biomass and distribution of phytoplankton and zooplankton (medium confidence).
The impact of present and future changes on higher predators, fish and fisheries will be regionally specific, with some beneficial and some detrimental effects [15.2.2].

Many Arctic human communities are already adapting to climate change (high confidence).
Indigenous people have exhibited resilience to changes in their local environments for thousands of years. Some indigenous communities are adapting through changes in wildlife management regimes and hunting practices. However, stresses in addition to climate change, together with a migration into small remote communities and increasing involvement in employment economies and sedentary occupations, will challenge adaptive capacity and increase vulnerability. Some traditional ways of life are being threatened and substantial investments are needed to adapt or relocate physical structures and communities [15.4.6, 15.5, 15.7].

A less severe climate in northern regions will produce positive economic benefits for some communities (very high confidence).
The benefits will depend on particular local conditions but will, in places, include reduced heating costs, increased agricultural and forestry opportunities, more navigable northern sea routes and marine access to resources [15.4.2].

The impacts of future climate change in the polar regions will produce feedbacks that will have globally significant consequences over the next hundred years (high confidence).

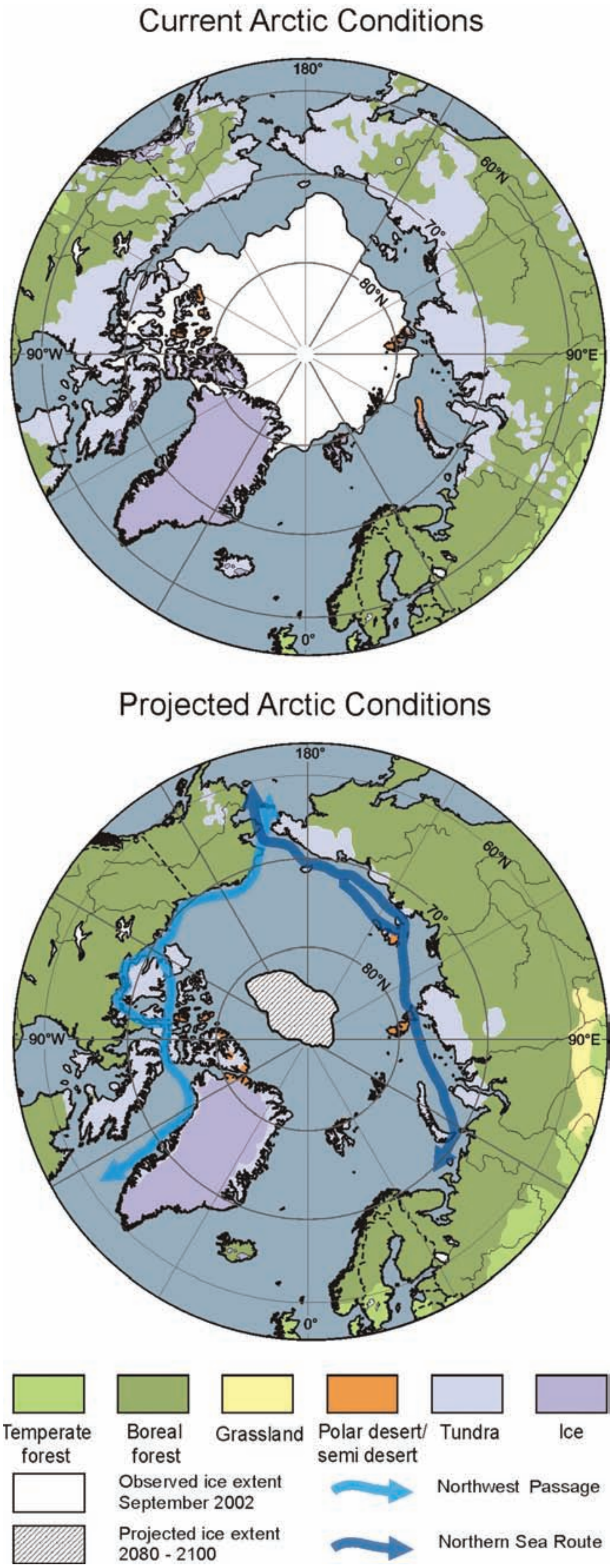


Figure TS.16. *Vegetation of the Arctic and neighbouring regions. Top: present-day, based on floristic surveys. Bottom: modelled for 2090-2100 under the IS92a emissions scenario. [F15.2]*

A continued loss of land-based ice will add to global sea-level rise. A major impact could result from a weakening of the thermohaline circulation due to a net increase in river flow into the Arctic Ocean and the resulting increased flux of freshwater into the North Atlantic. Under CO_2-doubling, total river flow into the Arctic Ocean is likely to increase by up to 20%. Warming will expose more bare ground in the Arctic (Figure TS.16) and on the Antarctic Peninsula, to be colonised by vegetation. Recent models predict a decrease in albedo due to loss of ice and changing vegetation, and that the tundra will be a small sink for carbon, although increased methane emissions from the thawing permafrost could contribute to climate warming [15.4.1, 15.4.2].

Small Islands

Small islands have characteristics which make them especially vulnerable to the effects of climate change, sea-level rise and extreme events (very high confidence).
These include their limited size and proneness to natural hazards and external shocks. They have low adaptive capacity, and adaptation costs are high relative to GDP [16.5].

Sea-level rise is likely to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening the vital infrastructure that supports the socio-economic well-being of island communities (very high confidence).
Some studies suggest that sea-level rise could cause coastal land loss and inundation, while others show that some islands are morphologically resilient and are expected to persist [16.4.2]. In the Caribbean and Pacific Islands, more than 50% of the population live within 1.5 km of the shore. Almost without exception, the air and sea ports, major road arteries, communication networks, utilities and other critical infrastructure in the small islands of the Indian and Pacific Oceans and the Caribbean tend to be restricted to coastal locations (Table TS.2). The threat from sea-level rise is likely to be amplified by changes in tropical cyclones [16.4.5, 16.4.7].

There is strong evidence that under most climate-change scenarios, water resources in small islands are likely to be seriously compromised (very high confidence).
Most small islands have a limited water supply. Many small islands in the Caribbean and Pacific are likely to experience increased water stress as a result of climate change [16.4.1]. Predictions under all SRES scenarios for this region show reduced rainfall in summer, so that it is unlikely that demand will be met during low rainfall periods. Increased rainfall in winter will be unlikely to compensate, due to a lack of storage and high runoff during storms [16.4.1].

Climate change is likely to heavily impact coral reefs, fisheries and other marine-based resources (high confidence).
Fisheries make an important contribution to the GDP of many island states. Changes in the occurrence and intensity of El Niño-Southern Oscillation (ENSO) events are likely to have severe impacts on commercial and artisanal fisheries. Increasing sea surface temperature and sea level, increased turbidity, nutrient loading and chemical pollution, damage from tropical cyclones, and decreases in growth rates due to the effects of higher CO_2-

concentrations on ocean chemistry, are very likely to lead to coral bleaching and mortality [16.4.3].

On some islands, especially those at higher latitudes, warming has already led to the replacement of some local species (high confidence).

Mid- and high-latitude islands are virtually certain to be colonised by non-indigenous invasive species, previously limited by unfavourable temperature conditions (see Table TS.2). Increases in extreme events in the short term are virtually certain to affect the adaptation responses of forests on tropical islands, where regeneration is often slow. In view of their small area, forests on many islands can easily be decimated by violent cyclones or storms. On some high-latitude islands it is likely that forest cover will increase [16.4.4, 15.4.2].

It is very likely that subsistence and commercial agriculture on small islands will be adversely affected by climate change (high confidence).

Sea-level rise, inundation, sea-water intrusion into freshwater lenses, soil salinisation and a decline in water supply will very likely adversely impact coastal agriculture. Away from the coast, changes in extremes (e.g., flooding and drought) are likely to have a negative effect on agricultural production. Appropriate adaptation measures may help to reduce these impacts. In some high-latitude islands, new opportunities may arise for increased agricultural production [16.4.3, 15.4.2].

New studies confirm previous findings that the effects of climate change on tourism are likely to be direct and indirect, and largely negative (high confidence).

Tourism is the major contributor to GDP and employment in many small islands. Sea-level rise and increased sea-water temperature are likely to contribute to accelerated beach erosion, degradation of coral reefs and bleaching (Table TS.2). In addition, loss of cultural heritage from inundation and flooding will reduce the amenity value for coastal users. Whereas a warmer climate could reduce the number of people visiting small islands in low latitudes, it could have the reverse effect in mid- and high-latitude islands. However, water shortages and increased incidence of vector-borne diseases are also likely to deter tourists [16.4.6].

There is growing concern that global climate change is likely to impact human health, mostly in adverse ways (medium confidence).

Many small islands lie in tropical or sub-tropical zones with weather conducive to the transmission of diseases such as malaria, dengue, filariasis, schistosomiasis, and food- and water-borne diseases. Outbreaks of climate-sensitive diseases can be costly in terms of lives and economic impact. Increasing temperatures and decreasing water availability due to climate change are likely to increase the burdens of diarrhoeal and other infectious diseases in some small-island states [16.4.5].

Latitude	Region and system at risk	Impacts and vulnerability
High	Iceland and isolated Arctic islands of Svalbard and the Faroe Islands: Marine ecosystem and plant species	• The imbalance of species loss and replacement leads to an initial loss in diversity. Northward expansion of dwarf-shrub and tree-dominated vegetation into areas rich in rare endemic species results in their loss. • Large reduction in, or even a complete collapse of, the Icelandic capelin stock leads to considerable negative impacts on most commercial fish stocks, whales and seabirds.
	High-latitude islands (Faroe Islands): Plant species	• Scenario I (temperature increase 2°C): species most affected by warming are restricted to the uppermost parts of mountains. For other species, the effect will mainly be upward migration. • Scenario II (temperature decrease 2°C): species affected by cooling are those at lower altitudes.
Mid	Sub-Antarctic Marion Islands: Ecosystem	• Changes will directly affect the indigenous biota. An even greater threat is that a warmer climate will increase the ease with which the islands can be invaded by alien species.
	Five islands in the Mediterranean Sea: Ecosystems	• Climate change impacts are negligible in many simulated marine ecosystems. • Invasion into island ecosystems becomes an increasing problem. In the longer term, ecosystems will be dominated by exotic plants irrespective of disturbance rates.
	Mediterranean: Migratory birds (pied flycatchers: *Ficedula hypoleuca*)	• Reduction in nestling and fledgling survival rates of pied flycatchers in two of the southernmost European breeding populations.
	Pacific and Mediterranean: Sim weed (*Chromolaena odorata*)	• Pacific Islands at risk of invasion by sim weed. • Mediterranean semi-arid and temperate climates predicted to be unsuitable for invasion.
Low	Pacific small islands: Coastal erosion, water resources and human settlements	• Accelerated coastal erosion, saline intrusion into freshwater lenses and increased flooding from the sea cause large effects on human settlements. • Lower rainfall coupled with accelerated sea-level rise compounds the threat on water resources; a 10% reduction in average rainfall by 2050 is likely to correspond to a 20% reduction in the size of the freshwater lens on Tarawa Atoll, Kiribati.
	American Samoa, fifteen other Pacific, Islands: Mangroves	• 50% loss of mangrove area in American Samoa; 12% reduction in mangrove area in fifteen other Pacific Islands.
	Caribbean (Bonaire, Netherlands Antilles): Beach erosion and sea-turtle nesting habitats	• On average, up to 38% (±24% standard deviation) of the total current beach could be lost with a 0.5 m rise in sea level, with lower narrower beaches being the most vulnerable, reducing turtle nesting habitat by one-third.
	Caribbean (Bonaire, Barbados): Tourism	• The beach-based tourism industry in Barbados and the marine-diving-based ecotourism industry in Bonaire are both negatively affected by climate change through beach erosion in Barbados and coral bleaching in Bonaire.

Table TS.2. *Range of future impacts and vulnerabilities in small islands [B16.1]. These projections are summarised from studies using a range of scenarios including SRES and Third Assessment Report sea-level rise projections.*

Box TS.6. The main projected impacts for regions

Africa

- The impacts of climate change in Africa are likely to be greatest where they co-occur with a range of other stresses (e.g., unequal access to resources [9.4.1]; enhanced food insecurity [9.6]; poor health management systems [9.2.2, 9.4.3]). These stresses, enhanced by climate variability and change, further enhance the vulnerabilities of many people in Africa. ** D [9.4]
- An increase of 5 to 8% (60 to 90 million ha) of arid and semi-arid land in Africa is projected by the 2080s under a range of climate-change scenarios. ** N [9.4.4]
- Declining agricultural yields are likely due to drought and land degradation, especially in marginal areas. Changes in the length of growing period have been noted under various scenarios. In the A1FI SRES scenario, which has an emphasis on globally-integrated economic growth, areas of major change include the coastal systems of southern and eastern Africa. Under both the A1 and B1 scenarios, mixed rain-fed, semi-arid systems are shown to be heavily affected by changes in climate in the Sahel. Mixed rain-fed and highland perennial systems in the Great Lakes region in East Africa and in other parts of East Africa are also heavily affected. In the B1 SRES scenario, which assumes development within a framework of environmental protection, the impacts are, however, generally less, but marginal areas (e.g., the semi-arid systems) become more marginal, with the impacts on coastal systems becoming moderate. ** D [9.4.4]
- Current stress on water in many areas of Africa is likely to be enhanced by climate variability and change. Increases in runoff in East Africa (possibly floods) and decreases in runoff and likely increased drought risk in other areas (e.g., southern Africa) are projected by the 2050s. Current water stresses are not only linked to climate variations, and issues of water governance and water-basin management must also be considered in any future assessments of water in Africa. ** D [9.4.1]
- Any changes in the primary production of large lakes are likely to have important impacts on local food supplies. For example, Lake Tanganyika currently provides 25 to 40% of animal protein intake for the population of the surrounding countries, and climate change is likely to reduce primary production and possible fish yields by roughly 30% [9.4.5, 3.4.7, 5.4.5]. The interaction of human management decisions, including over-fishing, is likely to further compound fish offtakes from lakes. ** D [9.2.2]
- Ecosystems in Africa are likely to experience major shifts and changes in species range and possible extinctions (e.g., fynbos and succulent Karoo biomes in southern Africa). * D [9.4.5]
- Mangroves and coral reefs are projected to be further degraded, with additional consequences for fisheries and tourism.** D [9.4.5]
- Towards the end of the 21st century, projected sea-level rise will affect low-lying coastal areas with large populations. The cost of adaptation will exceed 5 to 10% of GDP. ** D [B9.2, 9.4.6, 9.5.2]

Asia

- A 1 m rise in sea level would lead to a loss of almost half of the mangrove area in the Mekong River delta (2,500 km^2), while approximately 100,000 ha of cultivated land and aquaculture area would become salt marsh. * N [10.4.3]
- Coastal areas, especially heavily populated megadelta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers. For a 1 m rise in sea level, 5,000 km^2 of Red River delta, and 15,000 to 20,000 km^2 of Mekong River delta are projected to be flooded, which could affect 4 million and 3.5 to 5 million people, respectively. * N [10.4.3]
- Tibetan Plateau glaciers of under 4 km in length are projected to disappear with a temperature increase of 3°C and no change in precipitation. ** D [10.4.4]
- If current warming rates are maintained, Himalayan glaciers could decay at very rapid rates, shrinking from the present 500,000 km^2 to 100,000 km^2 by the 2030s. ** D [10.6.2]
- Around 30% of Asian coral reefs are expected to be lost in the next 30 years, compared with 18% globally under the IS92a emissions scenario, but this is due to multiple stresses and not to climate change alone. ** D [10.4.3]
- It is estimated that under the full range of SRES scenarios, 120 million to 1.2 billion and 185 to 981 million people will experience increased water stress by the 2020s and the 2050s, respectively. ** D [10.4.2]
- The per capita availability of freshwater in India is expected to drop from around 1,900 m^3 currently to 1,000 m^3 by 2025 in response to the combined effects of population growth and climate change [10.4.2.3]. More intense rain and more frequent flash floods during the monsoon would result in a higher proportion of runoff and a reduction in the proportion reaching the groundwater. ** N [10.4.2]
- It is projected that crop yields could increase up to 20% in East and South-East Asia, while they could decrease up to 30% in Central and South Asia by the mid-21st century. Taken together and considering the influence of rapid population growth and urbanisation, the risk of hunger is projected to remain very high in several developing countries. * N [10.4.1]
- Agricultural irrigation demand in arid and semi-arid regions of East Asia is expected to increase by 10% for an increase in

temperature of 1°C. ** N [10.4.1]
- The frequency and extent of forest fires in northern Asia are expected to increase in the future due to climate change and extreme weather events that would likely limit forest expansion. * N [10.4.4]

Australia and New Zealand

- The most vulnerable sectors are natural ecosystems, water security and coastal communities. ** C [11.7]
- Many ecosystems are likely to be altered by 2020, even under medium-emissions scenarios [11.4.1]. Among the most vulnerable are the Great Barrier Reef, south-western Australia, Kakadu Wetlands, rain forests and alpine areas [11.4.2]. This is virtually certain to exacerbate existing stresses such as invasive species and habitat loss, increase the probability of species extinctions, and cause a reduction in ecosystem services for tourism, fishing, forestry and water supply. * N [11.4.2]
- Ongoing water security problems are very likely to increase by 2030 in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions, e.g., a 0 to 45% decline in runoff in Victoria by 2030 and a 10 to 25% reduction in river flow in Australia's Murray-Darling Basin by 2050. ** D [11.4.1]
- Ongoing coastal development is very likely to exacerbate risk to lives and property from sea-level rise and storms. By 2050, there is very likely to be loss of high-value land, faster road deterioration, degraded beaches, and loss of items of cultural significance. *** C [11.4.5, 11.4.7, 11.4.8]
- Increased fire danger is likely with climate change; for example, in south-east Australia the frequency of very high and extreme fire danger days is likely to rise 4 to 25% by 2020 and 15 to 70% by 2050. ** D [11.3.1]
- Risks to major infrastructure are likely to increase. Design criteria for extreme events are very likely to be exceeded more frequently by 2030. Risks include failure of floodplain levees and urban drainage systems, and flooding of coastal towns near rivers. ** D [11.4.5, 11.4.7]
- Increased temperatures and demographic change are likely to increase peak energy demand in summer and the associated risk of black-outs. ** D [11.4.10]
- Production from agriculture and forestry by 2030 is projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits are projected in western and southern areas and close to major rivers due to a longer growing season, less frost and increased rainfall. ** N [11.4]
- In the south and west of New Zealand, growth rates of economically important plantation crops (mainly *Pinus radiata*) are likely to increase with CO_2-fertilisation, warmer winters and wetter conditions. ** D [11.4.4]
- Increased heat-related deaths for people aged over 65 are likely, with an extra 3,200 to 5,200 deaths on average per year by 2050 (allowing for population growth and ageing, but assuming no adaptation). ** D [11.4.11]

Europe

- The probability of an extreme winter precipitation exceeding two standard deviations above normal is expected to increase by up to a factor of five in parts of the UK and northern Europe by the 2080s with a doubling of CO_2. ** D [12.3.1]
- By the 2070s, annual runoff is projected to increase in northern Europe, and decrease by up to 36% in southern Europe, with summer low flows reduced by up to 80% under IS92a. ** D [12.4.1, T12.2]
- The percentage of river-basin area in the severe water stress category (withdrawal/availability higher than 0.4) is expected to increase from 19% today to 34 to 36% by the 2070s. ** D [12.4.1]
- The number of additional people living in water-stressed watersheds in the seventeen western Europe countries is likely to increase from 16 to 44 million based on HadCM3 climate under the A2 and B1 emission scenarios, respectively, by the 2080s. ** D[12.4.1]
- Under A1FI scenarios, by the 2080s an additional 1.6 million people each year are expected to be affected by coastal flooding. ** D [12.4.2]
- By the 2070s, hydropower potential for the whole of Europe is expected to decline by 6%, with strong regional variations from a 20 to 50% decrease in the Mediterranean region to a 15 to 30% increase in northern and eastern Europe. ** D [12.4.8]
- A large percentage of the European flora could become vulnerable, endangered, critically endangered or extinct by the end of the 21st century under a range of SRES scenarios. *** N [12.4.6]
- By 2050, crops are expected to show a northward expansion in area [12.4.7.1]. The greatest increases in climate-related crop yields are expected in northern Europe (e.g., wheat: +2 to +9% by 2020, +8 to +25% by 2050, +10 to +30% by 2080), while the largest reductions are expected in the south (e.g., wheat: +3 to +4% by 2020, –8 to +22% by 2050, –15 to +32% by 2080).*** C [12.4.7]
- Forested area is likely to increase in the north and decrease in the south. A redistribution of tree species is expected, and an elevation of the mountain tree line. Forest-fire risk is virtually certain to greatly increase in southern Europe. ** D [12.4.4]
- Most amphibian (45 to 69%) and reptile (61 to 89%) species are virtually certain to expand their range if dispersal were unlimited. However, if species were unable to disperse, then the range of most species (>97%) would become smaller, especially in the Iberian Peninsula and France. ** N [12.4.6]

- Small Alpine glaciers in different regions will disappear, while larger glaciers will suffer a volume reduction between 30% and 70% by 2050 under a range of emissions scenarios, with concomitant reductions in discharge in spring and summer. *** C [12.4.3]
- Decreased comfort of the Mediterranean region in the summer, and improved comfort in the north and west, could lead to a reduction in Mediterranean summer tourism and an increase in spring and autumn. ** D [12.4.9]
- Rapid shutdown of Meridional Overturning Circulation (MOC), although assigned a low probability, is likely to have widespread severe impacts in Europe, especially in western coastal areas. These include reductions in crop production with associated price increases, increased cold-related deaths, winter transport disruption, population migration to southern Europe and a shift in the economic centre of gravity. * N [12.6.2]

Latin America

- Over the next 15 years, inter-tropical glaciers are very likely to disappear, reducing water availability and hydropower generation in Bolivia, Peru, Colombia and Ecuador. *** C [13.2.4]
- Any future reductions in rainfall in arid and semi-arid regions of Argentina, Chile and Brazil are likely to lead to severe water shortages. ** C [13.4.3]
- By the 2020s between 7 million and 77 million people are likely to suffer from a lack of adequate water supplies, while for the second half of the century the potential water availability reduction and the increasing demand, from an increasing regional population, would increase these figures to between 60 and 150 million. ** D [13.ES, 13.4.3]
- In the future, anthropogenic climate change (including changes in weather extremes) and sea-level rise are very likely to have impacts on ** N [13.4.4]:
    - low-lying areas (e.g., in El Salvador, Guyana, the coast of Buenos Aires Province in Argentina);
    - buildings and tourism (e.g., in Mexico and Uruguay);
    - coastal morphology (e.g., in Peru);
    - mangroves (e.g., in Brazil, Ecuador, Colombia, Venezuela);
    - availability of drinking water in the Pacific coast of Costa Rica and Ecuador.
- Sea surface temperature increases due to climate change are projected to have adverse effects on ** N [13.4.4]:
    - Mesoamerican coral reefs (e.g., Mexico, Belize, Panama);
    - the location of fish stocks in the south-east Pacific (e.g., Peru and Chile).
- Increases of 2°C and decreases in soil water would lead to a replacement of tropical forest by savannas in eastern Amazonia and in the tropical forests of central and southern Mexico, along with replacement of semi-arid by arid vegetation in parts of north-east Brazil and most of central and northern Mexico. ** D [13.4.1]
- In the future, the frequency and intensity of hurricanes in the Caribbean Basin are likely to increase. * D [13.3.1]
- As a result of climate change, rice yields are expected to decline after the year 2020, while increases in temperature and precipitation in south-eastern South America are likely to increase soybean yields if CO_2 effects are considered. * C [13.4.2]
- The number of additional people at risk of hunger under the SRES A2 emissions scenario is likely to attain 5, 26 and 85 million in 2020, 2050 and 2080, respectively, assuming little or no CO_2 effects. * D [13.4.2]
- Cattle productivity is very likely to decline in response to a 4°C increase in temperatures. ** N [13.ES, 13.4.2]
- The Latin American region, concerned with the potential effects of climate variability and change, is trying to implement some adaptation measures such as:
    - the use of climate forecasts in sectors such as fisheries (Peru) and agriculture (Peru, north-eastern Brazil);
    - early-warning systems for flood in the Rio de la Plata Basin based on the 'Centro Operativo de Alerta Hidrológico'.
- The region has also created new institutions to mitigate and prevent impacts from natural hazards, such as the Regional Disaster Information Center for Latin America and the Caribbean, the International Centre for Research on El Niño Phenomenon in Ecuador, and the Permanent Commission of the South Pacific. *** D [13.2.5]

North America

- Population growth, rising property values and continued investment increase coastal vulnerability. Any increase in destructiveness of coastal storms is very likely to lead to dramatic increases in losses from severe weather and storm surge, with the losses exacerbated by sea-level rise. Current adaptation is uneven, and readiness for increased exposure is poor. *** D [14.2.3, 14.4.3]
- Sea-level rise and the associated increase in tidal surge and flooding have the potential to severely affect transportation and infrastructure along the Gulf, Atlantic and northern coasts. A case study of facilities at risk in New York identified surface road and rail lines, bridges, tunnels, marine and airport facilities and transit stations. *** D [14.4.3, 14.4.6, 14.5.1, B14.3]
- Severe heatwaves, characterised by stagnant, warm air masses and consecutive nights with high minimum temperatures, are likely to increase in number, magnitude and duration in cities where they already occur, with potential for adverse health effects. Elderly populations are most at risk. ** D [14.4.5]

- By mid-century, daily average ozone levels are projected to increase by 3.7 ppb across the eastern USA, with the most polluted cities today experiencing the greatest increases. Ozone-related deaths are projected to increase by 4.5% from the 1990s to the 2050s. * D [14.4.5]
- Projected warming in the western mountains by the mid-21st century is very likely to cause large decreases in snowpack, earlier snow melt, more winter rain events, increased peak winter flows and flooding, and reduced summer flows *** D [14.4.1].
- Reduced water supplies coupled with increases in demand are likely to exacerbate competition for over-allocated water resources. *** D [14.2.1, B14.2]
- Climate change in the first several decades of the 21st century is likely to increase forest production, but with high sensitivity to drought, storms, insects and other disturbances. ** D [14.4.2, 14.4.4]
- Moderate climate change in the early decades of the century is projected to increase aggregate yields of rain-fed agriculture by 5 to 20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilised water resources. ** D [14.4]
- By the second half of the 21st century, the greatest impacts on forests are likely to be through changing disturbances from pests, diseases and fire. Warmer summer temperatures are projected to extend the annual window of high fire risk by 10 to 30%, and increase area burned by 74 to 118% in Canada by 2100. *** D [14.4.4, B14.1]
- Present rates of coastal wetland loss are projected to increase with accelerated relative sea-level rise, in part due to structures preventing landward migration. Salt-marsh biodiversity is expected to decrease in north-eastern marshes. ** D [14.4.3]
- Vulnerability to climate change is likely be concentrated in specific groups and regions, including indigenous peoples and others dependent on narrow resource bases, and the poor and elderly in cities. ** D [14.2.6, 14.4.6]
- Continued investment in adaptation in response to historical experience rather than projected future conditions is likely to increase vulnerability of many sectors to climate change [14.5]. Infrastructure development, with its long lead times and investments, would benefit from incorporating climate-change information. *** D [14.5.3, F14.3]

Polar Regions

- By the end of the century, annually averaged Arctic sea-ice extent is projected to show a reduction of 22 to 33%, depending on emissions scenario; and in Antarctica, projections range from a slight increase to a near-complete loss of summer sea ice. ** D [15.3.3]
- Over the next hundred years there will important reductions in thickness and extent of ice from Arctic glaciers and ice caps, and the Greenland ice sheet ***, as a direct response to climate warming; in Antarctica, losses from the Antarctic Peninsula glaciers will continue ***, and observed thinning in part of the West Antarctic ice sheet, which is probably driven by oceanic change, will continue **. These contributions will form a substantial fraction of sea-level rise during this century. *** D [15.3.4, 15.6.3; WGI AR4 Chapters 4, 5]
- Northern Hemisphere permafrost extent is projected to decrease by 20 to 35% by 2050. The depth of seasonal thawing is likely to increase by 15 to 25% in most areas by 2050, and by 50% or more in northernmost locations under the full range of SRES scenarios. ** D [15.3.4]
- In the Arctic, initial permafrost thaw will alter drainage systems, allowing establishment of aquatic communities in areas formerly dominated by terrestrial species ***. Further thawing will increasingly couple surface drainage to the groundwater, further disrupting ecosystems. Coastal erosion will increase. ** D [15.4.1]
- By the end of the century, 10 to 50% of Arctic tundra will be replaced by forest, and around 15 to 25% of polar desert will be replaced by tundra. * D [15.4.2]
- In both polar regions, climate change will lead to decreases in habitat (including sea ice) for migratory birds and mammals [15.2.2, 15.4.1], with major implications for predators such as seals and polar bears ** [15.2, 15.4.3]. Changes in the distribution and abundance of many species can be expected. *** D [15.6.3]
- The climatic barriers that have hitherto protected polar species from competition will be lowered, and the encroachment of alien species into parts of the Arctic and Antarctic are expected. ** D [15.6.3, 15.4.4, 15.4.2]
- Reductions in lake and river ice cover are expected in both polar regions. These will affect lake thermal structures, the quality/quantity of under-ice habitats and, in the Arctic, the timing and severity of ice jamming and related flooding. *** N [15.4.1]
- Projected hydrological changes will influence the productivity and distribution of aquatic species, especially fish. Warming of freshwaters is likely to lead to reductions in fish stock, especially those that prefer colder waters. ** D [15.4.1]
- For Arctic human communities, it is virtually certain that there will be both negative and positive impacts, particularly through changing cryospheric components, on infrastructure and traditional indigenous ways of life. ** D [15.4]
- In Siberia and North America, there may be an increase in agriculture and forestry as the northern limit for these activities shifts by several hundred kilometres by 2050 [15.4.2]. This will benefit some communities and disadvantage others following traditional lifestyles. ** D [15.4.6]

- Large-scale forest fires and outbreaks of tree-killing insects, which are triggered by warm weather, are characteristic of the boreal forest and some forest tundra areas, and are likely to increase. ** N [15.4.2]
- Arctic warming will reduce excess winter mortality, primarily through a reduction in cardiovascular and respiratory deaths and in injuries. *** N [15.4.6]
- Arctic warming will be associated with increased vulnerability to pests and diseases in wildlife, such as tick-borne encephalitis, which can be transmitted to humans. ** N [15.4.6]
- Increases in the frequency and severity of Arctic flooding, erosion, drought and destruction of permafrost, threaten community, public health and industrial infrastructure and water supply. *** N [15.4.6]
- Changes in the frequency, type and timing of precipitation will increase contaminant capture and increase contaminant loading to Arctic freshwater systems. Increased loadings will more than offset the reductions that are expected to accrue from global emissions of contaminants. ** N [15.4.1]
- Arctic human communities are already being required to adapt to climate change. Impacts to food security, personal safety and subsistence activities are being responded to via changes in resource and wildlife management regimes and shifts in personal behaviours (e.g., hunting, travelling). In combination with demographic, socio-economic and lifestyle changes, the resilience of indigenous populations is being severely challenged. *** N [15.4.1, 15.4.2, 15.4.6, 15.6]

Small Islands

- Sea-level rise and increased sea-water temperature are projected to accelerate beach erosion, and cause degradation of natural coastal defences such as mangroves and coral reefs. It is likely that these changes would, in turn, negatively impact the attraction of small islands as premier tourism destinations. According to surveys, it is likely that, in some islands, up to 80% of tourists would be unwilling to return for the same holiday price in the event of coral bleaching and reduced beach area resulting from elevated sea surface temperatures and sea-level rise. ** D [16.4.6]
- Port facilities at Suva, Fiji, and Apia, Samoa, are likely to experience overtopping, damage to wharves and flooding of the hinterland following a 0.5 m rise in sea level combined with waves associated with a 1 in 50-year cyclone. *** D [16.4.7]
- International airports on small islands are mostly sited on or within a few kilometres of the coast, and the main (and often only) road network runs along the coast. Under sea-level rise scenarios, many of them are likely to be at serious risk from inundation, flooding and physical damage associated with coastal inundation and erosion. *** D [16.4.7]
- Coastal erosion on Arctic islands has additional climate sensitivity through the impact of warming on permafrost and massive ground ice, which can lead to accelerated erosion and volume loss, and the potential for higher wave energy. *** D [16.4.2]
- Reduction in average rainfall is very likely to reduce the size of the freshwater lens. A 10% reduction in average rainfall by 2050 is likely to correspond to a 20% reduction in the size of the freshwater lens on Tarawa Atoll, Kiribati. In general, a reduction in physical size resulting from land loss accompanying sea-level rise could reduce the thickness of the freshwater lens on atolls by as much as 29%. *** N [16.4.1]
- Without adaptation, agricultural economic costs from climate change are likely to reach between 2-3% and 17-18% of 2002 GDP by 2050, on high terrain (e.g., Fiji) and low terrain (e.g., Kiribati) islands, respectively, under SRES A2 (1.3°C increase by 2050) and B2 (0.9°C increase by 2050). ** N [16.4.3]
- With climate change, increased numbers of introductions and enhanced colonisation by alien species are likely to occur on mid- and high-latitude islands. These changes are already evident on some islands. For example, in species-poor sub-Antarctic island ecosystems, alien microbes, fungi, plants and animals have been causing a substantial loss of local biodiversity and changes to ecosystem function. ** N [16.4.4]
- Outbreaks of climate-sensitive diseases such as malaria, dengue, filariasis and schistosomiasis can be costly in lives and economic impacts. Increasing temperatures and decreasing water availability due to climate change is likely to increase burdens of diarrhoeal and other infectious diseases in some small-island states. ** D [16.4.5]
- Climate change is expected to have significant impacts on tourism destination selection ** D [16.4.6]. Several small-island countries (e.g., Barbados, Maldives, Seychelles, Tuvalu) have begun to invest in the implementation of adaptation strategies, including desalination, to offset current and projected water shortages. *** D [16.4.1]
- Studies so far conducted on adaptation on islands suggest that adaptation options are likely to be limited and the costs high relative to GDP. Recent work has shown that, in the case of Singapore, coastal protection would be the least-cost strategy to combat sea-level rise under three scenarios, with the cost ranging from US$0.3-5.7 million by 2050 to US$0.9-16.8 million by 2100. ** D [16.5.2]
- Although adaptation choices for small islands may be limited and adaptation costs high, exploratory research indicates that there are some co-benefits which can be generated from pursuing prudent adaptation strategies. For example, the use of waste-to-energy and other renewable energy systems can promote sustainable development, while strengthening resilience to climate change. In fact, many islands have already embarked on initiatives aimed at ensuring that renewables constitute a significant percentage of the energy mix. ** D [16.4.7, 16.6]